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FOREST PRODUCTS LABORATORY SERIES.

STRENGTH TESTS OF CROSS-ARMS.

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CONTENTS.

ILLUSTRATIONS.

STRENGTH TESTS OF CROSS-ARMS.

SERVICE LOADS ON CROSS-ARMS.

Cross-arms must resist forces which are variable in amount and direction. In a line the arms may be subjected to heavy loads under several conditions:

(1) If the wires on one side of a pole are broken, a heavy side pull comes on the cross-arm from the other side. This causes a severe stress in the pole, and, as will be shown later, the pole is more likely to be broken than the cross-arm.

(2) If the wires are heavily covered with sleet and there is a strong wind blowing, there is a pressure on the cross-arms, but here again the stress in the pole will cause it to fail before the cross-arm will give way. Similarly, in changes of direction in the line the sidewise pull of the wires is more severe on the poles than on the arms.

(3) If the cross-arms are at the same level in the line, they can receive no greater strains than those which may be imposed by the weight of the wires, and of adhering ice, and by wind pressure. If, however, the middle pole of three is higher than the poles on either side and the wires are tightly stretched, there is a strong downward pull on the cross-arms. A similar condition might result if a single pole were left standing in a line where the poles on either side had fallen.

It is not necessary to reproduce exactly these stresses in laboratory tests if one test can be devised to cover the most severe conditions and the resistance to the less severe estimated on the basis of that one test. A test was devised in which the load was distributed along the arm, as it is in actual practice. In all of the tests the load was applied vertically for two reasons: First, because the arms are likely to receive their heaviest loads in this direction; second, because from the results it is possible to estimate the resistance of the arms to forces acting in other directions. The test used is also well adapted to show the influence of defects on strength.

MATERIAL TESTED.

The material for the tests described in this circular consisted of 84 six-pin cross-arms $3\frac{1}{4}$ by $4\frac{1}{4}$ inches by 6 feet (fig. 1). This number was made up of seven groups and comprised four species: Douglas fir, shortleaf pine, longleaf pine, and southern white cedar.

Group 1—12 arms, Douglas fir.
Group 2—12 arms, shortleaf pine.
Group 3—13 arms, longleaf pine, graded by the manufacturers as 50 per cent heart.
Group 4—11 arms, longleaf pine, 75 per cent heart.
Group 5—12 arms, longleaf pine, 100 per cent heart.
Group 6—12 arms, southern white cedar.
Group 7—12 arms, shortleaf pine, creosoted.

Group 1 originated at a mill at Walville, Wash.; groups 2 and 7 at Buell, Va.; groups 3, 4, and 5 at Hattiesburg, Miss.; and group 6 near Norfolk, Va. Groups 1, 2, 3, 4, 5, and 7 were furnished by the American Cross-Arm Co. and group 6 by the John L. Roper Lumber Co. The tests were made at the Forest Products Laboratory, maintained in cooperation with the University of Wisconsin, at Madison. All arms were open-piled in the laboratory from two to eight weeks before the testing work was begun.

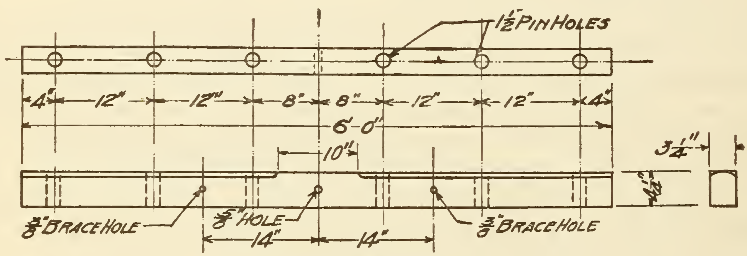

FIG. 1.—Standard 6-foot 6-pin cross-arm.

NOTE.—The arms tested varied in height from 3.95 to 4.23 inches and in width from 3.05 to 3.24 inches. Positions of pinholes varied frequently from ½ to ¾ inch. Brace holes were 16, 18, or 19 inches from center in some groups. Such arms were rebored and brace holes placed 14 inches from center.

METHOD OF TESTS.

Tests were made on a 200,000-pound Riehle universal testing machine. The arrangement of the apparatus is shown in figure 2. The stub pole *f* rests on a short beam on two posts, which in turn rest on the weighing platform. The pole is held in a vertical position by the columns of the testing machine. A gain about 1 inch deep is cut in the side of the pole, and the cross-arm is fastened into it by a ⅝-inch bolt which extends through the pole. That portion of the bolt within the pole is encased in a piece of gas pipe which fits the bolt closely and increases its bearing on the wood. The outer end of this bolt is supported by a heavy brace *b*, consisting of a piece of ½ by 1¾ inch round-edge tire steel, the lower end of which is attached to the pole by a ⅞-inch bolt. The diagonal braces are ¼ by 1¼ inch steel, 24 inches long, from center to center of the bolt holes. The lower ends of these braces are attached to the pole 19½ inches below the center of the cross-arm by a ⅝-inch bolt through the pole, this bolt also being encased in the pole in a piece of gas pipe. The upper

ends of the braces are attached to the cross-arms by ⅜-inch carriage bolts at points 14 inches from the center of the arm and in line with the center bolt.

The center bolt is braced for the reason (found by experimenting on one or two arms) that without the brace the bolt bends and stretches to such an extent that the arm twists or skews out of its

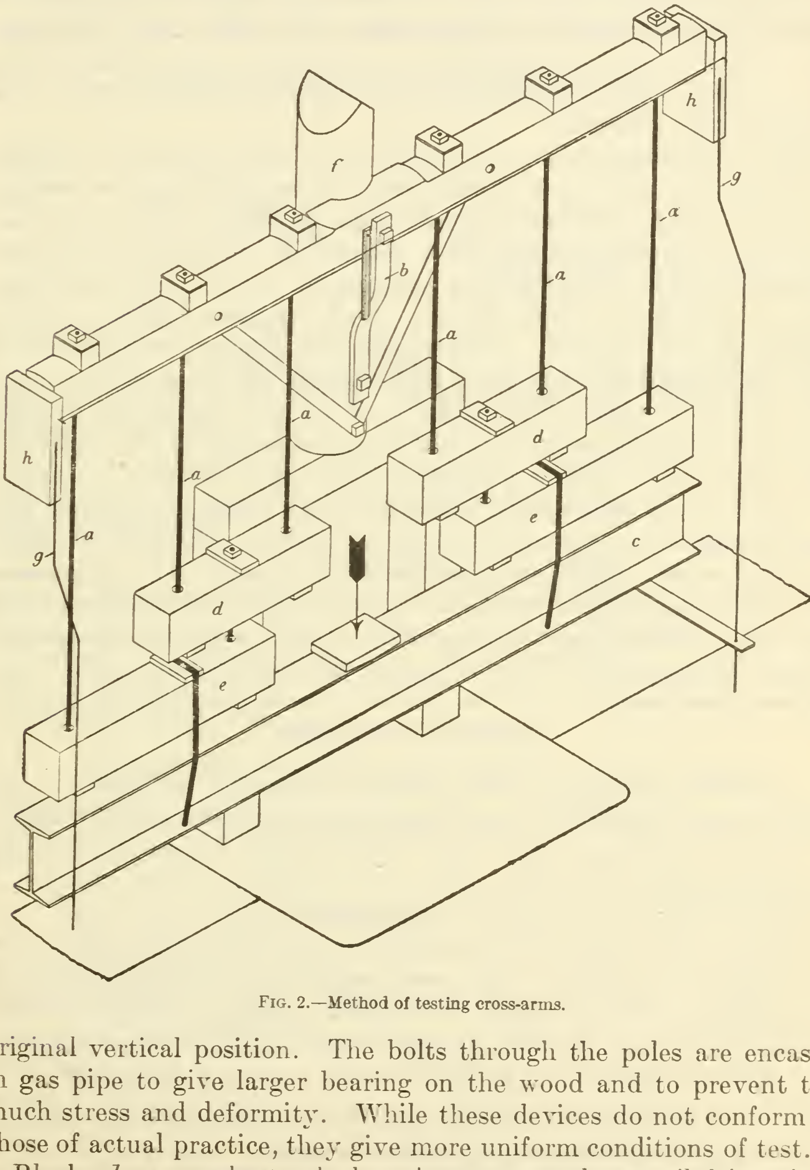

Fig. 2.—Method of testing cross-arms.

original vertical position. The bolts through the poles are encased in gas pipe to give larger bearing on the wood and to prevent too much stress and deformity. While these devices do not conform to those of actual practice, they give more uniform conditions of test.

Blocks, h, are each attached to the cross-arm by a nail driven into the center of its end. These blocks are held vertical by the guide

rods, *g*. A nail is driven part way into the front edge of each block and in line with the center of the cross-arm. Between these two nails is stretched a fine wire, which is kept taut by a rubber band. The movement of this wire with respect to a scale in the center of the arm marks the deflection.

The load is applied to the cross-arm by rods passing through the pinholes in the arms. Nuts on these rods pull down on wooden bearing blocks shaped to fit the upper side of the arm. The lower ends of these rods are attached to the system of equalizing levers (*c*, *d*, and *e*), whose arrangement is such that the rods transmit equal loads to the cross-arm.

In conducting the tests an initial load of 250 pounds was applied. The scale and wire were then adjusted to zero reading, the machine started,[1] and a deflection reading taken at 500 pounds and at each increment of 500 pounds until a perceptible weakening of the arm was noted, after which the load was read for each 0.1-inch deflection, and at points of sudden change, until complete failure or 4-inch deflection was secured. A load-deflection diagram was plotted as the test progressed, and from this diagram the values given in the tables were derived. The behavior of the arm during the test was observed carefully, and the character and sequence of the failures described. Each arm was weighed at the time of test.

One arm was tested from each group, then a second arm from each group, and so on, in order that there might be eliminated from the comparison any variation in results due to change in the apparatus. All arms, except four from each group, which were selected to be saved for exhibit, were cut up, and a 1-inch moisture disk and an 8-inch specimen for test in compression parallel to grain[2] were secured from each.

RESULTS OF TESTS.

A detailed summary of the results is presented in Table 1. The load at ½-inch deflection is an approximate measure of the stiffness. "Work to maximum load" and "total work" are measures of the toughness. The maximum load is the measure of the strength or ability to withstand a slowly applied load.

A few of the tests were incomplete or unsatisfactory; while these are included in Table 1, they were omitted from the calculation of the averages which are given in this table. Also, in certain cases the failure of the arms was due, at least in part, to knots and cross-grain. The values obtained in the tests of such arms are printed in italics (Table 1), and these, as well as the tests omitted from the averages

[1] The head descended uniformly at the rate of 0.26 inch per minute.

[2] The compression tests were made in accordance with the procedure described in Forest Service Circular 38, "Instructions to Engineers of Timber Tests."

in Table 1, were omitted in computing the average values given in Table 2.

Since the stresses between the points of attachment of the braces are indeterminate, no allowance has been made for variation in size except to estimate what the maximum loads would have been had the average dimensions of the arms of all groups been the same as those of the Douglas fir group (3.16 by 4.10 inches). These estimated loads are inclosed in parentheses in Table 2.

TABLE 2.—*Summary of results of tests on cross-arms.*

Species and grade.	Rings per inch.	Summer wood.	Sap.	Moisture.	Specific gravity, dry.	Bending tests.				Compression parallel to grain.
						Load at ½-inch deflection.	Maximum load.	Work to maximum load.	Total work.	Maximum crushing strength.
	Number.	*Per cent.*	*Per cent.*	*Per cent.*		*Pounds.*	*Pounds.*	*Inch-pounds.*	*Inch-pounds.*	*Pounds per square inch.*
Douglas fir	20	40	0	11.5	0.479	4.050	7,590 ([1]7,590)	5,990	15,730	7,080
Longleaf pine, 50 per cent heart	17.9	43.7	55	13.4	.542	4.463	8,984 (9,000)	6,888	13.565	5,425
Longleaf pine, 75 per cent heart	18.5	53	32	13.5	.627	5,220	10,180 (10,240)	7,800	18,370	8,950
Longleaf pine, 100 per cent heart	15.5	44	1	12.8	.627	4.770	9,782 (9,850)	7,970	18.543	8,940
Shortleaf pine	10.5	46	79	13.3	.516	4,460	9,260 (9.220)	8,400	16.510	7,300
Shortleaf pine, creosoted	11.2	49	......	......	......	3.841	7,649 (7.360)	6,084	14.325	5,770
White cedar	12	45	1.5	14.3	.364	2.860	5,200 (4.800)	3.150	6.930	4.700

[1] Values in parentheses are the estimated maximum loads for arms 4.10 by 3.16 inches in cross section (the average size of Douglas fir arms).

COMPARATIVE STRENGTH OF VARIOUS KINDS OF WOOD.

The various species and grades in order of average strength are as follows:

	Average maximum load.
Longleaf pine, "75 per cent heart"	10,180
Longleaf pine, "100 per cent heart"	9,780
Shortleaf pine	9,260
Longleaf pine. "50 per cent heart"	8,980
Shortleaf pine. creosoted	7,650
Douglas fir	7,590
White cedar	5,200

Since the arms with 75 per cent of heart are stronger than those with 100 per cent, and those with 50 per cent are weaker, other factors than the relative amounts of heartwood and sapwood must

have a determining influence on the strength.[1] This is the more apparent in the light of the fact that the actual per cents of heart are, by careful estimate, 100, 68, and 45, respectively, instead of 100, 75, and 50, according to the nominal grading.

There was a very considerable difference in the strength of the natural and treated shortleaf pine arms. Just how much of this difference should be attributed to the treatment it is impossible to determine, but a careful examination of the failures indicates that the creosoted arms were, aside from the treatment, inferior to the untreated.

Both the strength values and the manner of failure show that white cedar is considerably less strong than the other species. The failure is in nearly all cases by short brash tension. The numerous small knots and the large season checks seem to have had little influence on the failures.

INFLUENCE OF DEFECTS.

In nearly all cases the principal failure was at the first pinhole from the center, though in many cases the first failure was apparent as a cracking at the center bolt hole. In view of these facts it is recommended that, in grading or selecting arms, particular attention be given to defects near the center or the first pinholes. Knots on the upper side of the arm near these points are especially to be avoided.

SUMMARY.

The average load borne by the Southern white cedar cross-arms, the weakest group, was 5,000 pounds, the load being applied vertically. By careful estimate the resistance of these arms to side pull is at least 4,000 pounds. Under any conditions of service this is more than sufficient, because it is so much greater than the side load that can be sustained by poles. In tests[2] these have not withstood an average side pull of much more than 3,000 pounds, and usually have failed at less than 2,000. Further, both the pole and cross-arm tests were made on air-dry material, while under actual conditions of use the poles would be weakened by moisture much more than the cross-arms.

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[1] This finding is in accord with the general results from timber tests of the Forest Service, that heartwood and sapwood are about equally strong.

[2] Pole tests by the Forest Service gave the following figures for the side pull (applied at the top end of the pole) which a 25-foot pole of 7-inch top diameter is able to withstand:

Western red cedar at 15.1 per cent moisture	1,310 pounds.
Lodgepole pine (fire killed) at 16.9 per cent moisture	1,430 pounds.
Engelmann spruce (fire-killed) at 16.3 per cent moisture	1,405 pounds.

Tests by the Pacific Telephone and Telegraph Company gave the following figures for 25, 30, and 35-foot poles having top diameters of 6, 7, 8, and 9 inches:

Western red cedar (Idaho) at 10.1 per cent moisture	2,215 pounds.
Western red cedar (Oregon and Washington) at 15.2 per cent moisture	1,930 pounds.
Port Orford cedar (Oregon) at 12.0 per cent moisture	3,040 pounds.

In the case of sleet or snow, if the ice coating on the wires gives each strand a diameter of 1 inch, a wind pressure of 27 pounds per square foot would be sufficient to break the pole, assuming that the poles have a resistance to side pressure of 2,000 pounds, and are 150 feet apart. Even under these extreme conditions the cross-arm would have to resist stresses equivalent to those imposed by a load of only 875 pounds, applied as in the tests, so that even the weakest of the arms tested would have more than sufficient strength to withstand a force which would break the average pole.

Where there are abrupt changes of grade in a line, as in the case of one pole higher than those adjacent on either side, the downward pull on the cross-arm depends on the stress of the wires and their inclination from the horizontal. If 6 No. 8 wires are stretched to their maximum strength, assumed to be 60,000 pounds per square inch, they can exert a pull of 7,670 pounds. If a cross-arm on the middle pole had the average strength of Southern white cedar, it could not be broken by such a pull unless the pole were at least 45 feet higher than the two at each side, the spans being 150 feet. Such an abrupt change in grade is rare in practice. If the cross-arm were weakened to 60 per cent of its air-dry strength, which would correspond to a green or water-soaked condition, the arm would not break unless the difference in height were at least 25 feet.

All things considered, cross-arms of the species and dimensions tested are strong enough for ordinary use; with longer arms the strength is relatively of much more importance. With the standard 6-foot cross-arm, however, the question of strength need not enter into calculations of line construction, except in the rare case of abrupt change in grade. The ability of the timber to resist decay, and methods of preventing decay, are considerations of greater importance.[1]

[1] See Forest Service Circular 151, "The Preservative Treatment of Loblolly Pine Cross-Arms," by W. F. Sherfesee.

TABLE 1.—*Detailed summary of tests on cross-arms.*

[NOTE.—Italics indicate arms which failed at defects.]

DOUGLAS FIR (SHIPMENT 91).

Piece No.	Rings per inch.	Summer wood.	Sap.	Moisture.	Specific gravity dry.	Bending tests. Arms mounted on stub pole and braced. Loaded at six pinholes.										Maximum fiber stress in compression parallel to grain.
						Height at center.	Width at center.	Load at ½-inch deflection.	Maximum load.	Deflection at maximum load.	Load at 4-inch deflection.	Total deflection.	Work to maximum load.	Total work.	Kind of failure.[1]	
		Per cent.	*Per cent.*	*Per cent.*		*Inches.*	*Inches.*	*Pounds.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*	*Inch-pounds.*	*Inch-pounds.*		*Pounds per sq. inch.*
1	18	63	0	12.9	0.646	4.16	3.19	....	....	....	....	....	....	....	This arm used in experimenting on method of test.	7,500
2	23½	35	0	10.7	.397	4.17	3.19	4,190	7,140	1.90	2,650	4.00	10,066	19,608	Tension failure at center and pinhole[2] followed by compression failure at pinholes.	6,290
3	......	......	0	....	....	4.07	3.11	3,700	7,940	1.50	4,600	4.00	7,590	22,840	Tension failure at center and compression failure at pinholes.	....
4	23½	37	0	11.8	.410	4.11	3.16	3,450	6,480	1.10	0	1.30	4,200	5,440	Tension and compression failures at pinholes.	6,060
5	15½	55	0	11.9	.592	4.10	3.15	5,100	9,000	1.30	2,350	4.00	7,590	17,240	Splitting at center bolt followed by tension failure between center and pinhole.	8,760
6	15½	30	0	11.4	.477	4.06	3.16	2,175	4,500	1.10	2,150	4.00	3,170	10,420	Cross-grain tension failure, with compression failure at pinholes.	7,320
7	32	31	5	12.0	.506	4.07	3.12	4,200	8,300	1.00	4,900	4.00	4,440	21,580	Splitting at center bolt followed by tension and compression failures at pinhole.	7,860
8	12½	27	0	11.9	.422	4.11	3.15	4,000	8,000	1.55	1,500	4.00	8,160	13,580	Splitting at center bolt followed by tension and compression failures at pinholes.	6,270
9	......	......	0	....	....	4.16	3.16	5,000	7,900	0.80	4,050	4.00	3,400	17,150	Tension failures at pinhole, splitting at center bolt, and light compression failures at pinholes.	....
10	......	......	0	....	....	4.11	3.20	4,650	8,550	1.20	1,500	4.00	6,300	15,980	Splitting at center bolt followed by tension and compression failures at pinholes.	....
11	20	40	0	12.1	.452	4.05	3.16	4,000	8,050	1.10	2,850	4.00	4,980	13,500	Splitting at center bolt with tension failure at pinhole.	6,600
12	......	......	0	....	....	4.09	3.15	5,000	5,500	0.70	....	0.80	2,224	2,460	Tension failure at center (imperfect test).	....
Average	20	40	.42	11.5	.479	4.10	3.16	4,050	7,590	1.26	2,655	3.73	5,990	15,730	Pieces 1 and 12 omitted	7,080

LONGLEAF PINE—50 PER CENT HEART (SHIPMENT 91).

13	......	......	85	....	....	4.06	3.15	5,250	10,340	1.40	0	2.00	9,152	15,180	Splitting at center bolt followed by tension and compression failures at pinhole.	....
14	......	......	65	....	....	4.18	3.20	4,475	9,320	1.30	0	2.30	7,212	7,930	Splitting at center bolt; almost complete tension failure at pinhole.	....
15	24½	41	60	11.2	0.578	4.09	3.11	4,850	9,860	1.20	0	3.70	7,030	13,780	Splitting at center bolt followed by tension failure at knot and compression failure at pinhole.	8,740
16	20	42	60	13.5	.462	3.95	3.11	3,400	7,700	1.40	1,700	4.00	6,512	11,220	Compression and tension failure at pinhole.	6,640
17	17	44	55	14.0	.587	4.16	3.18	4,300	9,450	1.30	2,300	4.00	7,140	12,920	Tension failure at center and pinhole....	7,930
18	*7½*	*45*	*10*	*14.5*	*.534*	*4.03*	*3.17*	*4,025*	*7,750*	*1.10*	*1,700*	*4.00*	*4,772*	*10,360*	Tension failure at knot near center and compression failure at pinhole.	7,960
19	21	48	35	13.1	.560	4.07	3.11	4,975	9,550	1.20	2,750	4.00	6,980	20,360	Splitting at center bolt followed by tension and compression failures at pinholes.	7,990
20	19	46	70	13.5	.595	4.09	3.13	5,650	9,150	1.00	2,650	4.00	5,360	18,000	Splitting at center bolt with tension failure at pinhole.	8,780
21	8	41	5	13.5	.541	4.03	3.17	4,050	8,150	1.10	2,000	4.00	5,010	10,400	Tension failure at pinhole................	7,300
22	16	45	60	14.8	.473	4.06	3.21	3,850	8,000	1.19	0	1.19	5,420	5,420	Complete brash tension failure at pinhole.	8,250
23	......	......	35	....	....	4.08	3.10	4,300	9,700	1.70	2,400	4.00	11,360	22,910	Splitting at center bolt followed by compression and tension failures at pinhole.	....
24	......	......	*35*	....	....	*4.07*	*3.12*	*4,125*	*7,500*	*0.99*	*1,600*	*4.00*	*4,240*	*10,460*	Splitting at center bolt followed by tension failure at knot at pinhole and compression failure at pinhole.	....
25	16	43	35	13.2	.485	4.14	3.21	4,000	7,600	1.05	2,800	4.00	4,600	11,100	Splitting at center bolt followed by tension failure at pinhole.	6,940
Average	16½	44	47	13.5	.542	4.08	3.15	4,400	8,775	1.23	1,530	3.48	6,520	13,080	....	5,425

LONGLEAF PINE—75 PER CENT HEART (SHIPMENT 91).

26	......	......	10	....	....	4.05	3.16	4,175	9,100	1.40	2,400	4.00	7,730	17,180	Tension failure at center and compression failure at pinhole.	....
27	8	45	50	13.4	0.623	4.10	3.20	5,250	10,400	1.20	1,950	4.00	7,200	15,780	Tension failure at center and compression and tension failure at pinhole.	8,810
28	......	......	50	....	....	4.12	3.13	5,075	8,510	1.00	1,850	4.00	4,780	12,060	Tension failure center to pinhole; compression failure at pinhole.	....
29	8½	54	25	13.5	.678	4.07	3.11	4,225	8,680	1.00	3,750	4.00	4,580	17,560	Tension failure pinhole to pinhole; compression failure at pinhole.	8,570
30	26	52	50	12.7	.583	4.06	3.18	4,800	9,650	1.20	2,400	4.00	6,860	16,960	Tension and compression failures at pinhole.	8,710
31	26½	50	15	13.5	.611	4.05	3.17	5,450	10,800	1.50	3,200	4.00	10,250	22,200	Compression and tension failures at pinholes.	8,910

[1] Definitions of the terms used to describe the kinds of failure are given in Forest Service Circular 38 (Revised), "Instructions to Engineers of Timber Tests."
[2] Where the words "pinhole" or "pinholes" are used in these descriptions the pinholes 8 inches from the center of the arm are meant.

TABLE 1.—*Detailed summary of tests on cross-arms*—Continued.

LONGLEAF PINE—75 PER CENT HEART (SHIPMENT 91)—Continued.

Piece No.	Rings per inch.	Summer wood.	Sap.	Moisture.	Specific gravity dry.	Bending tests. Arms mounted on stub pole and braced. Loaded at six pinholes. Height at center.	Width at center.	Load at ½-inch deflection.	Maximum load.	Deflection at maximum load.	Load at 4-inch deflection.	Total deflection.	Work to maximum load.	Total work.	Kind of failure.	Maximum fiber stress in compression parallel to grain.
		Per cent.	*Per cent.*	*Per cent.*		*Inches.*	*Inches.*	*Pounds.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*	*Inch-pounds.*	*Inch-pounds.*		*Pounds per sq. inch.*
32	......	......	50	....	....	4.20	3.16	5,750	11,250	1.40	1,850	4.00	10,020	21,700	Compression failures at pinholes; splitting at center bolt; tension failure at pinhole.	....
33	15½	65	10	14.5	.687	4.21	3.07	6,250	12,100	1.30	2,850	4.00	9,740	22,740	Splitting at center bolt; compression and tension failures at pinhole.	10,400
34	27	47	40	13.8	.538	4.13	3.22	4,850	9,950	1.66	0	1.66	10,580	10,580	Slight splitting at center bolt; sudden and complete tension failure at pinhole.	7,580
35	19	58	5	13.0	.671	4.02	3.13	6,600	10,850	1.00	3,650	4.00	6,360	24,140	Split at center belt; tension failure at pinhole; splitting at center bolt; compression failure at pinhole.	9,680
36	......	......	45	....	....	3.98	3.16	5,000	10,650	1.20	2,400	4.00	7,400	21,160	Split at center bolt; tension and compression failures at pinhole, with increased split at center bolt.	....
Average	18½	53	32	13.5	.627	4.09	3.15	5,220	10,180	1.26	2,390	3.79	7,800	18,370	....	8,950
LONGLEAF PINE—100 PER CENT HEART (SHIPMENT 91).																
37	12	34	0	12.1	0.504	4.10	3.13	4,150	9,120	1.20	2,450	4.00	6,208	14,620	Splitting at center bolt; tension failure at center; tension and compression failures at pinholes.	7,880
38	......	......	0	....	....	4.15	3.16	5,150	8,490	1.00	1,450	4.00	5,100	14,510	Splitting at center bolt; tension and compression failures at pinhole.	....
39	......	......	0	....	....	4.12	3.16	4,350	9,710	1.30	1,825	4.00	7,260	20,320	Compression failure at pinhole; horizontal shear failure along check; tension and compression failures at pinholes.	....
40	20	43	0	12.1	.576	4.05	3.11	3,900	8,450	1.10	2,350	4.00	4,980	15,160	Tension failure pinhole to center and center to brace; tension and compression failures at pinholes.	8,500
41	13½	54	0	15.9	.683	4.10	3.10	5,100	11,350	1.60	2,650	4.00	11,800	18,400	Splitting at center bolt; tension failure at center and pinhole; compression failure at pinhole.	9,260
42	15½	48	5	11.3	.583	4.10	3.13	5,050	10,400	1.20	3,250	4.00	7,180	19,540	Tension failure at pinhole; split center to pinhole; tension and compression failures at pinhole.	9,240

43	18	48	0	13.0	.752	4.15	3.05	5,050	10,400	1.70	4,600	4.00	12,280	25,200	Splitting at center bolt; tension and compression failures at pinhole.	10,500
44	12	43	5	12.6	.658	4.05	3.10	5,450	11,000	1.30	4,000	4.00	8,740	21,480	Splitting at center bolt, followed by tension and compression failures at pinhole.	10,200
45	18	34	0	12.3	.565	4.23	3.20	3,850	4,750	0.90	......	......	......	......	This arm tested with support at center only; failure by brash tension at pinhole.	7,410
46	......	......	5	......	......	4.15	3.14	4,500	9,350	1.40	3,150	4.00	8,230	17,240	Splitting at center; tension failure at center and pinhole.	......
47	15½	50	0	12.6	.636	4.15	3.13	5,075	9,550	1.30	3,850	4.00	7,920	18,960	Split at center bolt; tension failure at pinhole; increased split at center bolt, with tension failure at center and compression failure at pinholes.	8,560
48	......	......	*0*	......	......	*4.00*	*3.16*	*4,150*	*8,250*	*1.03*	*2,500*	*4.00*	*4,560*	*13,780*	Split at center bolt, with tension failure at knot near center, split extending to pinhole.	......
Average	15.2	46	1.25	12.8	.627	4.10	3.13	4,720	9,643	1.27	2,920	4.00	7,660	18,110	Piece No. 45 omitted	8,940

SHORTLEAF PINE (SHIPMENT 95).

1	17	43	95	......	......	4.15	3.19	3,300	6,790	1.10	0	3.50	4,144	7,770	Sudden tension failure at pinhole	......
2	13	43	90	13.3	.587	4.13	3.18	4,850	8,840	1.00	2,500	4.00	5,060	15,020	Tension failure pinhole to center bolt; compression and tension failures at pinhole.	7,950
3	11	38	65	13.6	.597	4.11	3.16	4,950	9,910	1.37	800	4.00	8,400	13,400	Split at center bolt; compression failure at pinhole; tension failure pinhole to center and at opposite pinhole.	8,190
4	......	......	75	......	......	4.06	3.13	4,900	9,900	2.00	3,150	4.00	14,460	20,950	Tension failure near center; split at center bolt; tension failure to left of center and compression failure at pinhole.	......
5	7	62	100	12.9	.768	4.11	3.14	4,350	10,000	1.40	3,500	4.00	8,190	16,680	Tension failure pinhole to center, afterwards extending to opposite pinhole.	6,660
6	7	46	90	12.8	.529	4.12	3.18	3,225	9,350	1.50	1,800	4.00	8,060	16,940	Compression failure at pinhole; tension failure pinhole to center.	6,380
7	......	......	55	......	......	4.15	3.12	5,000	9,850	1.20	3,900	4.00	7,040	25,100	Compression failures at pinholes; tension failure at center.	......
8	8	31	95	13.2	.479	4.19	3.20	3,550	6,900	1.60	2,300	4.00	7,680	12,540	Tension failure. Arm tested wrong side up by mistake.	5,550
9	8½	60	100	13.8	.630	4.14	3.14	4,200	9,200	1.40	1,700	4.00	7,870	12,620	Tension failure at pinhole	8,430
10	10½	40	75	13.8	.460	4.16	3.13	4,800	9,100	1.50	0	3.80	8,980	13,700	Split at center bolt; compression and tension failures at pinhole; complete tension failure at pinhole.	7,240
11	12	49	95	13.1	.580	4.13	3.15	5,300	11,300	1.60	3,300	4.00	11,080	28,480	Compression failures at pinholes; tension failure in central portion of arm.	8,020
12	......	......	15	......	......	4.05	3.11	5,050	10,000	1.49	1,600	4.00	9,840	14,900	Splitting at center bolt followed by tension failure at center.	......
Average	10½	46	79	13.3	.516	4.12	3.15	4,460	9,260	1.43	2,050	3.94	8,400	16,510	......	7,300

TABLE 1.—*Detailed summary of tests on cross-arms*—Continued.

SHORTLEAF PINE—CREOSOTED (SHIPMENT 106).

Piece No.	Rings per inch.	Summer wood.	Sap.	Moisture.	Specific gravity dry.	Bending tests. Arms mounted on stub pole and braced. Loaded at six pinholes. Height at center.	Width at center.	Load at ½-inch deflection.	Maximum load.	Deflection at maximum load.	Load at 4-inch deflection.	Total deflection.	Work to maximum load.	Total work.	Kind of failure.	Maximum fiber stress in compression parallel to grain.
		Per cent.	*Per cent.*	*Per cent.*		*Inches.*	*Inches.*	*Pounds.*	*Pounds.*	*Inches.*	*Pounds.*	*Inches.*	*Inch-pounds.*	*Inch-pounds.*		*Pounds per sq. inch.*
1	13	47	......	......	......	4.20	3.20	3,800	7,470	1.20	2,900	4.00	5,484	16,420	Tension failure center to pinhole; increased tension failure; compression failure and increased tension failure at pinhole.	6,340
2	......	......	......	......	......	4.16	3.21	3,725	7,900	1.20	2,050	4.00	5,320	14,860	Tension failure center to pinhole; compression failure at pinhole; tension failure at pinhole.	......
3	......	......	......	......	......	4.20	3.20	4,150	9,120	1.90	3,600	4.00	12,320	26,120	Tension failure at center with compression failure at pinholes.	......
4	......	......	......	......	......	*4.15*	*3.19*	*4,150*	*7,740*	*1.10*	*2,550*	*4.00*	*4,800*	*11,720*	Sudden failure tension at pinhole	......
5	*14*	*54*	......	......	......	*4.12*	*3.16*	*4,200*	*6,750*	*0.80*	*3,000*	*4.00*	*2,860*	*17,140*	Cross-grain tension failure center to pinhole; compression failure at pinhole; increase of first failure.	5,470
6	13	40	......	......	......	4.19	3.18	4,875	8,100	1.00	2,500	4.00	4,760	14,640	Splitting at center bolt; tension failure center to pinhole; increased tension failure with compression failure at pinhole.	7,060
7	......	......	......	......	......	*4.20*	*3.18*	*3,425*	*8,650*	*1.40*	*1,900*	*4.00*	*6,720*	*9,880*	Sudden tension failure at pinhole	......
8	6	50	......	......	......	4.23	3.15	3,650	8,500	1.30	0	1.30	6,140	6,140	Very brash complete tension failure at pinhole.	5,570
9	10	48	......	......	......	*4.16*	*3.17*	*4,800*	*7,900*	*0.90*	*4,350*	*4.00*	*3,780*	*16,980*	Cross-grain tension failure, extending from pinhole and passing below center bolt.	5,940
10	12	37	......	......	......	4.15	3.21	2,800	4,700	0.95	0	3.13	2,630	4,330	Tension failure at pinhole	5,210
11	14	47	......	......	......	4.20	3.20	3,550	5,500	0.79	0	3.70	2,260	8,290	Splitting at center bolt; brash tension failure at pinhole.	5,190
12	9½	75	......	......	......	4.15	3.17	4,175	9,900	1.60	3,450	4.00	9,760	23,800	Tension failure at center; compression failure at pinhole; tension failure center to pinhole; increased tension and compression failures at pinhole.	5,360
Average	11½	50	......	......	......	4.17	3.18	3,940	7,690	1.18	2,190	3.68	5,570	13,360	......	5,770

WHITE CEDAR (SHIPMENT 99).

1	......	......	0	....	....	4.23	3.16	2,525	6,000	1.30	1,900	4.00	4,622	8,820	Sudden tension failure at pinhole	....
2	12	65	0	15	.368	4.25	3.16	2,850	5,240	0.90	0	3.80	2,526	8,172	Brash tension failure at pinhole; compression failure at pinhole; increased tension failure at pinhole.	4,780
3	12	45	3	14.7	.388	4.25	3.13	3,900	6,930	1.40	0	3.10	6,020	9,520	Sudden tension failure just inside pinhole; compression and further tension at point of first failure.	5,060
4	20½	43	0	14.9	.386	4.25	3.19	2,950	3,950	0.80	0	3.00	1,620	4,430	Nearly complete tension failure at pinhole, continuing until arm broke in two.	4,580
5	12	60	3	16.7	.413	4.25	3.24	3,050	7,450	1.60	0	3.00	7,440	8,860	Splitting at center bolt; compression failure at pinhole; split at center; tension failure at pinhole; complete tension failure.	5,490
6	9½	31	5	13.4	.351	4.19	3.16	2,600	4,700	0.90	1,550	4.00	2,240	5,820	Brash tension failure at pinhole	4,550
7	7	40	0	14.1	.292	4.25	3.16	1,625	3,850	1.10	0	3.10	2,250	2,940	Sudden failure by brash tension at pinhole.	3,520
8	......	......	0	....	....	4.24	3.20	3,650	6,850	1.00	1,450	4.00	3,700	11,870	Compression and tension failures at pinholes.	....
9	10	38	5	13.3	.337	4.23	3.21	2,525	3,400	0.70	0	2.30	1,400	1,700	Splitting at center bolt, followed by very brash complete tension failure at pinhole.	4,510
10	......	......	2	....	....	4.25	3.19	2,800	5,050	0.85	1,300	4.00	2,180	7,320	Sudden tension failure at pinhole	....
11	13	35	0	12.1	.381	4.20	3.16	3,000	3,950	0.62	0	2.80	1,280	4,180	Successive brash tension failures. Arm badly checked before test.	5,110
12	......	......	0	....	....	4.18	3.21	2,900	5,050	0.90	2,200	4.00	2,500	9,540	Compression failure at pinhole; slightly cross-grain tension failure pinhole to center; increased compression failure.	....
Average	12	45	1.50	14.3	.364	4.23	3.18	2,860	5,200	1.01	700	3.42	3,150	6,930	....	4,700

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